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Original Article

AN EXPERIMENTAL INVESTIGATION OF THE IMPACT OF NANOPARTICLES ON THE TRIBOLOGICAL PROPERTIES OF 15W40 LUBRICATING OIL

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ABSTRACT

The objective of this research is to investigate the effect of various nanoparticles (SiO_2, WS_2, Cu, CuO and graphite) on the tribological properties of 15W40 Lubricating oil. The nanoparticles blended in the lubricant homogenously using magnetic stirring and ultrasonication, surfactant was used in the case of Cu and CuO nanoparticles to enhance the stability of nanolubricant. The tribological testing of the nanolubricant was carried out on four ball tester according to ASTM- D4172 for wear preventive characteristics of the lubricant and ASTM- DIN 51350-02 for extreme pressure test of liquid lubricant. The experimental analysis showed that the coefficient of friction (COF) and wear scar diameter (WSD) reduced by using the nanoparticles in the lubricant. The reduction of COF is maximum in case of SiO_2 nanolubricant 15%-25% followed by graphite nanolubricant ≈15%-18%, WS_2 nanolubricant ≈13%-21% and Cu nanolubricant ≈9%-20%, CuO showed minimum reduction in COF ≈1.5%-17%. The reduction in WSD in case of SiO_2 nanolubricant ≈50%-59%, graphite nanolubricant ≈45%-57%, WS_2 nanolubricant ≈17%-26%, Cu and CuO showed ≈33%-49% and ≈13%-28% respectively. The percentage increments in the weld load were maximum in case of CuO nanolubricant ≈29%, followed by WS_2 nanolubricant ≈27%. In case of Cu nanolubricant, SiO_2 nanolubricant, Graphite nanolubricant improvement is about ≈22%, 11%, 19% respectively.

KEYWORDS: Nanoparticles, Nanolubricant, Tribology, Friction Modifiers, Anti-Wear & Extreme Pressure Behaviour

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INTRODUCTION

Effort has been made to develop advanced lubricating oil to improve the tribological properties of the tribopair and service life. The introduction of nanoparticles makes them promising contender as it possess better physical and chemical properties than the base material. The nanoparticles blended in lubricating oil emerged as new tool for improving the tribological properties and service life of the lubricant.

When the dimensions of any material got reduced to nano level, a significant change appears in the physical, chemical and mechanical properties as compared to the bulk material. The 2D structure and reduced grain size of nanoparticles enables large surface area to volume ratio, large surface energy, high hardness and high toughness [1].

The lubricant serves the prime function of reducing friction by avoiding material to material contact, it also provides an atmospheric insulation to the material [2]. The majority of the lubricants have about 90% of hydrocarbons rest is organic phosphorus and sulfide compounds used as a performance booster for the lubricant. The nanoparticles may prove to be the correct replacement of the harmful lubricant additives as they reduce

friction and wear, and provide high extreme pressure performance of the lubricant [3-6] The tribological properties enhancement by the use of nanoparticles in the lubricant as additives ~ 2% w/w may be due to; rolling effect provided by the nanoparticles as the tribopair interface resulting in low friction and wear, low melting point melts and get deposited in the tribopair surface resulting in the reduction of friction and wear, nanoparticles may enter the cracks on the surface of tribopair, reduces friction and wear. The blending of solid particles (nanoparticles) increases extreme pressure properties of the lubricant [7-11]. Copper nanopowder in lubricating oil produced in-situ thin layer over the tribopair hence reduces friction at higher loads and higher sliding speeds [12-14]. Graphite nanosheets blended with paraffin oil (1.0×10^{-2}wt%) tested on four ball tester improved tribological and extreme pressure performance of paraffin [15]. Nanoparticles of SiO_2 blended in 15W40 lubricating oil was rheologicaly stable and improved anti-wear and anti-friction property of 15W40 lubricating oil [16,17]. WS_2 nanoparticles added to paraffin and SA 90 lubricating oil showed significant decrement in wear and friction force got reduced ~ 50% [18]. CuO nanoparticles blended in the lubricant showed ~ 273% improvement in load carrying capacity and slight improvement in the tribological properties due to formation of tribo-sintered layer of CuO over the tribopairs [19,20]

It has been observed from the literature that the blending of nanoparticles in the lubricant showed significant decrement in wear and friction, moreover improved the service life of the lubricant. Hence the nanoparticles may be used as lubricant blenders to produce advanced lubricant. Thus the objective of this study is to produce a stable nanolubricant and investigate the influence of various nanoparticles (SiO_2, WS_2, Cu, CuO and graphite) on the tribological properties of 15W40 Lubricating oil.

EXPERIMENTAL SETUP

The experimentation started with blending of nanoparticles in the 15W40 lubricating oil, the magnetic stirrer and Ultrasonicator were used for blending. The tribological testing was carried out on four ball tester and the wear scar diameter was measured using optical microscope.

Preparation of Nanolubricant

The nanolubricants had been prepared by blending the nanoparticles of graphite, Cu, CuO, SiO_2 and WS_2 in 15W40 lubricating oil. The blending techniques used for producing the nanolubricant and the stability are as shown in the Table 1.

Table 1: Preparation and Stability of Nanolubricant

Nanoparticles	Base Fluid	Surfactant	Blending Technique	Stability of Nanolubricant
Graphite Nanoparticles	15W40	-	Stirring for 2 hours at 70^0 C and 2000 rpm and then untrasonication at 20 kHz, 400W full pulse for 60 minutes.	The nanolubricant showed no sedimentation after 30 days of blending.
SiO_2 Nanoparticles	15W40	-	Stirring for 2 hours at 70^0 C and 2000 rpm and then untrasonication at 20 kHz, 400W full pulse for 3 hours.	The nanolubricant showed no sedimentation after 30 days of blending

Table 1: Contd.,

Cu Nanoparticles	15W40	CTAB	Stirring for 2 hours at 70^0 C and 2000 rpm and then untrasonication at 20 kHz, 400W full pulse for 6 hours in succession of 1 hour.	The nanolubricant showed sedimentation after 15 days of blending
CuO Nanoparticles	15W40	CTAB	Stirring for 2 hours at 70^0 C and 2000 rpm and then untrasonication at 20 kHz, 400W full pulse for 6 hours in succession of 1 hour.	The nanolubricant showed sedimentation after 19 days of blending
WS_2 Nanoparticles	15W40	-	Stirring for 2 hours at 70^0 C and 2000 rpm and then untrasonication at 20 kHz, 400W full pulse for 8 hours in succession of 60 minutes.	The nanolubricant showed no sedimentation after 30 days of blending

Tribological Testing

The tribological testing for the prepared nanolubricant had been carried out on four ball tester according to ASTM- DIN 51350 for extreme pressure and ASTM- D4172 for friction and wear characteristics of the lubricating oil.

In the four ball tester the load is applied from vertically downward direction. The upper ball rotates with constant rpm. The temperature of the assembly is maintained at the desired value by temperature controlled unit. The value of frictional torque of the experiment is directly measured by using a load sensor, which helps in calculating the coefficient of friction.

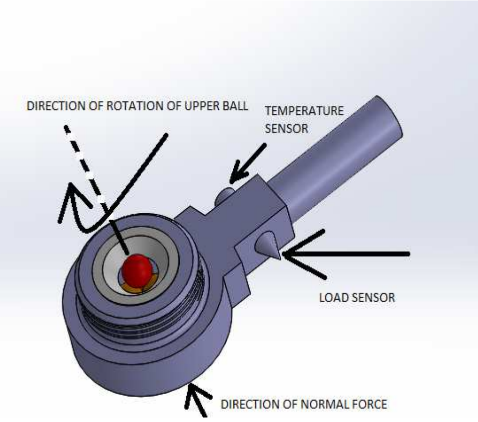

Figure 1: Four Ball Tester Schematic

Table 2: Parameters of Four Ball Tester

Parameters	Wear Test	Extreme Pressure Test
ASTM	ASTM- D4172	ASTM- DIN 51350-02
Ball Specimen	Steel Balls, Diameter 12.7 mm, Ra=0.04 microns, Hardness RC 65	Steel Balls, Diameter 12.7 mm, Ra=0.04 microns, Hardness RC 65
Oil Specimen	15W40 and 15W40blended with graphite nanoparticles	15W40 and 15W40blended with graphite nanoparticles
Load	196 N, 392 N, 588 N	Incremental Load Starting from 2000 N
Rotational speed of top ball	1200 rpm	1450 rpm
Temperature	75 ^{o}C	Ambient
Test Duration	60 minutes	60 s

RESULTS AND DISCUSSIONS

In the present analysis the prepared nanolubricants were tested on Four Ball Tester for their performance analysis by measuring coefficient of friction and wear scar diameter and stability was analyzed by means of weld load measurement.

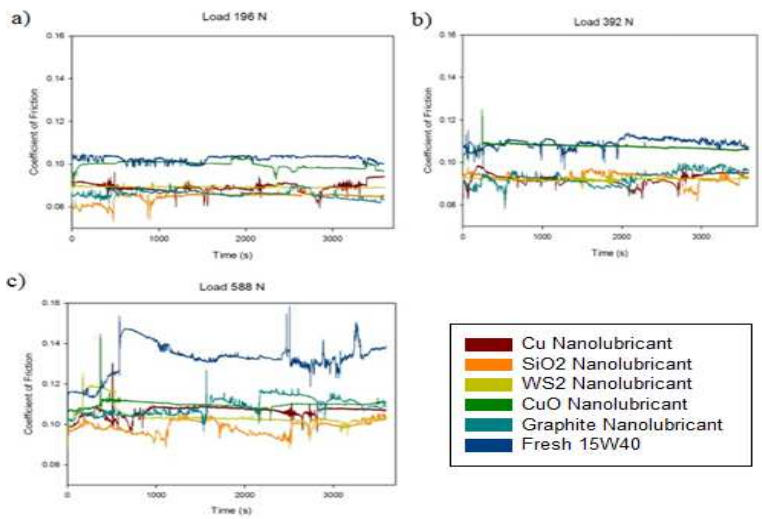

Figure 2: Load v/s Coefficient of Friction in Presence of Various Lubricants a) At Load 196 N, b) At Load 392 N, c) At Load 588 N

Coefficient of Friction

The experiment was performed on three loads 196 N, 392 N and 588 N. The coefficient of the friction is (COF) increased as the load is increased. The lubricant blended with nanoparticles had lower values of coefficient of friction as compared to the fresh lubricant. Table 3 shows the percentage of decrease in the value of the coefficient of friction as

compared to fresh15W40 lubricating oil. The nanoparticles of SiO_2 blended with 15W40 lubricating oil showed ~ 15% to 25% decrease in COF. The nanoparticles of graphite showed ~ 15% - 18% decrement in COF. The nanoparticles of Cu and CuO showed ~ 9% - 20% and ~ 1.5% to 17% reduction in COF respectively, whereas the nanoparticle of WS_2 showed ~ 13% - 21% decrease in COF.

Table 3: Percentage Decrease in COF Values in Presence of Nanoparticles in the Lubricant

Nano Lubricant	Percent Decrease in Coefficient of Friction		
	Load 196 N	Load 392 N	Load 588 N
SiO_2 Nanolubricant	17.46%	15.44%	25.55%
Graphite Nanolubricant	16.23%	15.4%	17.72%
Cu Nanolubricant	13.65%	9.07%	19.6%
CuO Nanolubricant	2.78%	1.48%	17%
WS_2 Nanolubricant	13.64%	15.12%	21.13%

Wear Scar Diameter

The wear scar diameter (WSD) was examined for all three loads 196 N, 392 N and 588 N. The Wear scar diameter increased as the load increased. The nanoparticles in the lubricant decreased the Wear scar diameter significantly. Table 4 shows the percentage of decrease in the value of the Wear scar diameter as compared to fresh15W40 lubricating oil. The nanoparticles of SiO_2 blended with 15W40 lubricating oil showed ~ 50% to 59% decrease in WSD. The nanoparticles of graphite showed ~ 45% - 57% decrement in WSD. The nanoparticles of Cu and CuO showed ~ 33% - 49% and ~ 13% to 28% reduction in WSD respectively, whereas the nanoparticle of WS_2 showed ~ 17% - 26% decrease in WSD.

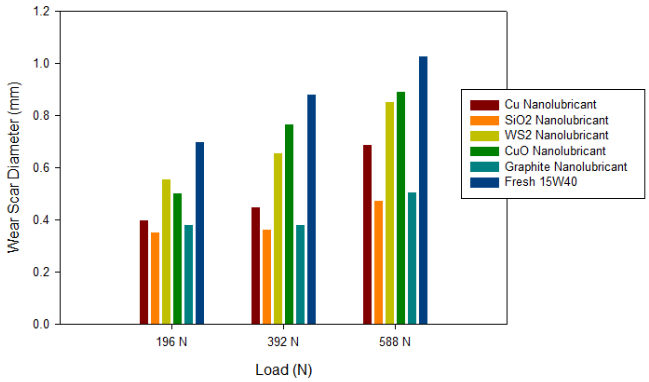

Figure 3: Load v/s Wear Scar Diameter in the Presence of Various Lubricants

Table 4: Percentage Decrease in WSD Values in Presence of Nanoparticles in the Lubricant

Nanolubricant	Percent decrease in Wear Scare Diameter		
	Load 196 N	Load 392 N	Load 588 N
SiO_2 Nanolubricant	49.64%	59.91%	54.15%
Graphite Nanolubricant	45.32%	56.82%	50.73%
Cu Nanolubricant	43.16%	49.40%	33.17%
CuO Nanolubricant	28.06%	13.07%	13.17%
WS_2 Nanolubricant	20.14%	25.57%	17.07%

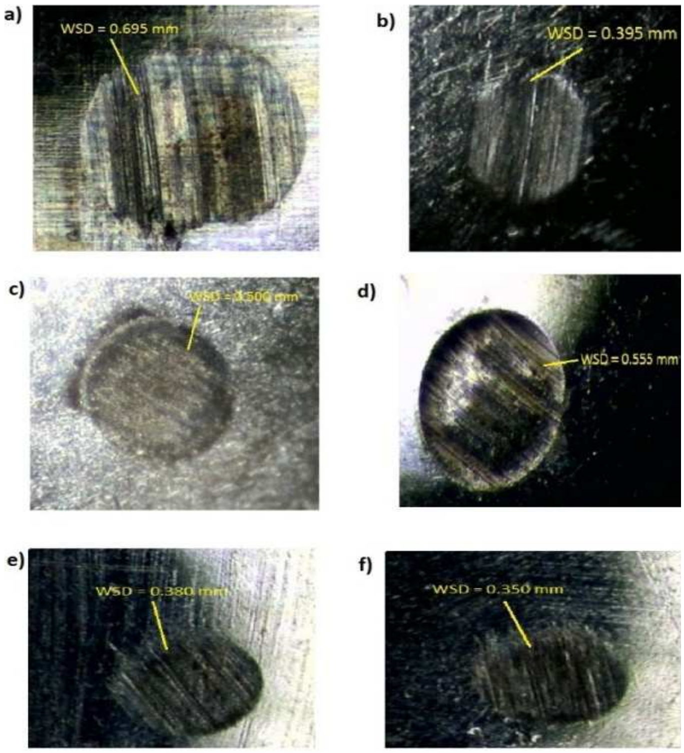

Figure 4: Wear Scar Diameter Observed by Optical Microscope at 196 N a) 15W40 Lubricant, b) Cu Nanolubricant, c) CuO Nanolubricant, d) ws_2 Nanolubricant, e) Graphite Nanolubricant, f) SiO_2 Nanolubricant

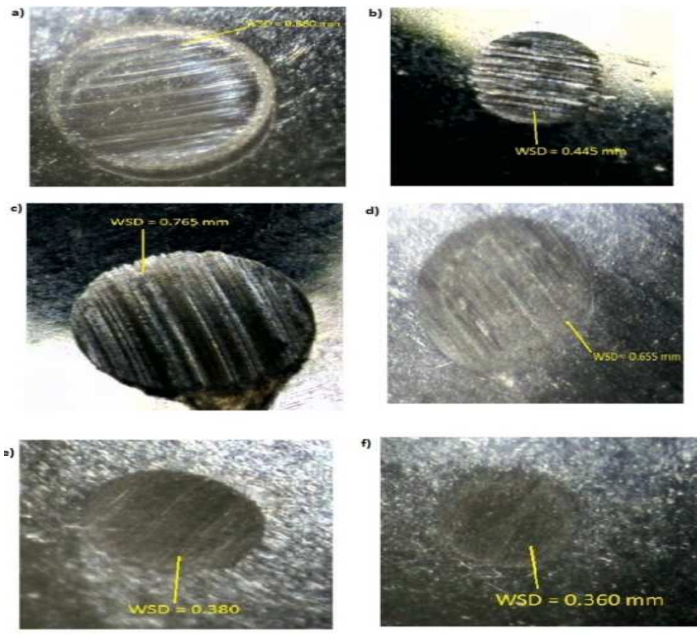

Figure 5: Wear Scar Diameter Observed by Optical Microscope at 392 N a) 15W40 Lubricant, b) Cu Nanolubricant, c) CuO Nanolubricant, d) WS_2 Nanolubricant, e) Graphite Nanolubricant, f) SiO_2 Nanolubricant

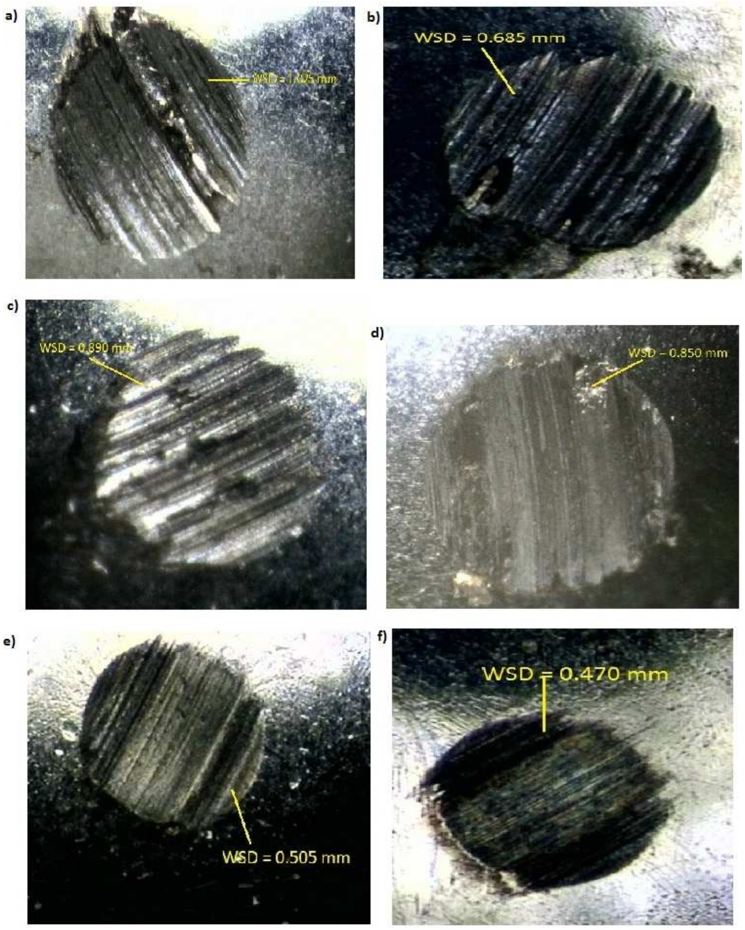

Figure 6: Wear Scar Diameter Observed by Optical Microscope at 588 N
a) 15W40 Lubricant, b) Cu Nanolubricant, c) CuO Nanolubricant,
d) WS_2 Nanolubricant, e) Graphite Nanolubricant, f) SiO_2 Nanolubricant.

Extreme Pressure Analysis

The extreme pressure performance of the prepared nanolubricant was conducted according to ASTM- DIN 51350. The weld load was calculated for each nanolubricant and compared with Fresh 15W40 lubricating oil. The extreme pressure performance of the nanolubricant showed better results than the fresh 15W40 Lubricating oil. The percentage increases in the weld load for Cu nanolubricant, SiO_2 nanolubricant, WS_2 nanolubricant, CuO nanolubricant and Graphite nanolubricant obtained ~ 22%, 11%, 27%, 29% and 19% respectively.

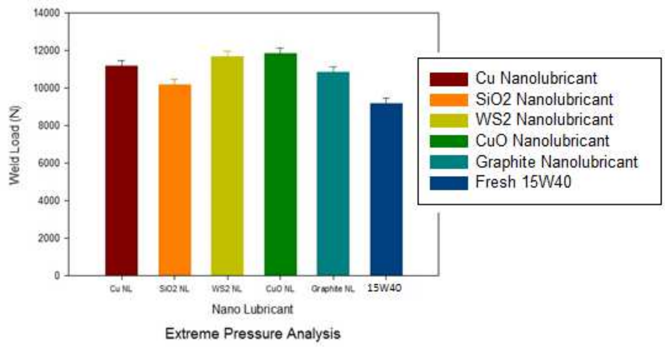

Figure 7: Extreme Pressure Analysis of Lubricants

CONCLUSIONS

The nanoparticles were blended homogeneously in 15W40 lubricating oil with the help of mechanical stirring and ultrasonication. In case of Cu and CuO nanoparticles, CTAB was used as surfactant to improve the dispersion and stability.

The antiwear characteristics of the nanolubricant were tested on four ball tester according to ASTM- D4172 showed improved tribological performance. The coefficient of friction for SiO_2 nanolubricant showed ~ 15% to 25% decrease in COF. The nanoparticles of graphite showed ~ 15% - 18% decrement in COF. The nanoparticles of Cu and CuO showed ~ 9% - 20% and ~ 1.5% to 17% reduction in COF respectively, whereas the nanoparticle of WS_2 showed ~ 13% - 21% decrease in COF.

There was a significant reduction in the wear scar diameter recorded when measured by optical microscope. In case of SiO_2 nanolubricant WSD decreased by ~ 50% to 59%. The graphite nanolubricant showed ~ 45% - 57% decrement in WSD. Cu and CuO nanolubricant showed ~ 33% - 49% and ~ 13% to 28% reduction in WSD respectively whereas the WS_2nanolubricant showed ~ 17% - 26% decrease in WSD.

The extreme pressure analysis was conducted according to ASTM- DIN 51350-02. There was a significant increase in the weld load in the case of nanolubricants which indicated the improved extreme pressure performance of the nanolubricant. The percentage increment in the weld load for Cu nanolubricant SiO_2 nanolubricant, WS_2 nanolubricant, CuO nanolubricant and Graphite nanolubricant obtained ~ 22%, 11%, 27%, 29% and 19% respectively.

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